Renewable and Sustainable Energy Reviews 16 (2012) 4515–4521

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

An analysis of energy use and relation between energy inputs and yield in tangerine production

Ahmad Mohammadshirazi *, Asadolah Akram, Shahin Rafiee, Seyyed Hashem Mousavi Avval, Elnaz Bagheri Kalhor

Department of Agricultural Machinery Engineering, Faculty of Agricultural Engineering and Technology, University of Tehran, Karaj, Iran

ARTICLE INFO

Article history:
Received 20 February 2012
Received in revised form
22 April 2012
Accepted 28 April 2012
Available online 26 June 2012

Keywords:
Tangerine
Cobb–Douglas
Energy use patterns
Energy input–output analysis

ABSTRACT

The objective of this study is to determine energy balance between inputs and output for tangerine production in Mazandaran province, one of the most important citrus production centers in Iran. Data is collected by administering a questionnaire in face-to-face interviews. The results show that the highest share of energy was utilized by application of chemical fertilizers and chemicals. Average yield and energy consumption are calculated as 26862.5 kg ha^{-1} and 62260.9 MJ ha^{-1}, respectively. The energy productivity and net energy value are estimated as 0.43 kg MJ^{-1} and $-$8201.4 MJ ha^{-1}, respectively. The ratio of energy outputs to energy inputs is approximately 0.87. In addition, the Cobb–Douglas production function is applied to estimate the econometric relationship among different forms of energy consumption. The findings suggest that tangerine producers must optimize their use of indirect and non-renewable energy resources; they apply an excess use of some energy inputs, resulting in an inverse effect on yield as well as imposing risks to natural resources and human health.

Contents

1. Introduction

Citrus fruits are among the most abundant crops in the world with an annual production of over 88 million tons. Almost 33% of the crops, including orange, lemons, grapefruit and mandarins, are industrially processed for juice production, where about half of the processed citrus including peels, segment membrane and seeds end up as wastes [1].

Energy use in agriculture has developed in response to increased population, limited supply of arable land and desire for an increasing standard of living. Many studies have been conducted to determine the energy efficiency of plant production, such as energy use pattern in a typical village in arid zone, soybean and wheat crops in India, sunflower in Greece, citrus fruits, sweet cherry and some field crops and vegetable in turkey, maize and sorghum in the United States [2]. Modern crop production is characterized by the high input of fossil energy, which is consumed as “direct energy” (fuel and electricity used on the farm) and as “indirect energy” (energy expended beyond the farm for the manufacture of fertilizers, plant protection agents, machines, etc.). Both direct and indirect forms of energy are required

* Corresponding author. Tel.: +98 2612801011; fax: +98 2612808138.
E-mail address: ahmad_mshirazi@ut.ac.ir (A. Mohammadshirazi).

1364-0321/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.rser.2012.04.047

for agricultural productions in terms of its development and growth. On the other hand, despite its importance, energy use can be very costly. Energy input–output analysis is usually used to evaluate the efficiency and environmental impacts of production systems. Considerable researches have been conducted on energy use in agriculture [3,4].

It is realized that crop yields and food supplies are directly linked to energy. In the developed countries, an increase in the crop yield was mainly due to an increase in the commercial energy inputs in addition to improved crop varieties. Accordingly, mathematical function needs to be specified to obtain a relationship between inputs and yield [5]. Agriculture is both a producer and consumer of energy. It uses large quantities of locally available non-commercial energies, such as seed, manure and animate energy, and commercial energies directly and indirectly in the form of diesel, electricity, fertilizer, plant protection, chemicals, irrigation water, machinery etc. Efficient use of these energies helps to achieve increased production and productivity and contributes to economy, profitability and competitiveness of agriculture sustainability to rural living [6]. Renewable energy sources coming from agricultural crops could play an important role to supply the energy requirement and in terms of environmental effects [7]. Energy input–output relationships in cropping systems vary with the crops grown in a sequence, type of soils, nature of tillage operations for seed bed preparation, nature and amount of organic manure and chemical fertilizers, plant protection measures, harvesting and threshing operations, yield levels and biomass production. Increasing modernization, in general, involves larger inputs of energy in crop production [8]. Finally, it was concluded that as the energy input increased, the production also increased [9].

Energy is a fundamental ingredient in the process of economic development, as it provides essential services that maintain economic activity and the quality of human life. Thus, shortages of energy are a serious constraint on the development of low income countries [10,11]. In order to sustain agricultural production, effective energy use in agriculture is required, since it provides financial savings, preservation of fossil resources [12]. Therefore, research efforts have emphasized energy and economic analysis of various agricultural productions for planning resources in the ecosystems [13].

Natural resources are traditionally described as energy resources and material resources. Wall introduced the concept of exergy, which is a unified measure of matter, energy and information, into resource accounting [14,15]. Exergy for a given system is defined as the maximal amount of work that can be extracted from the system in the process of reaching equilibrium with its local environment, chosen to have a direct bearing on the behavior of the system with respect to the time and length scales, depending on the observer's objectives and knowledge [16–21].

Shortages are caused or aggravated by widespread technical inefficiencies, capital constraints and a pattern of subsidies that undercut incentives for conservation [22]. Hetz studied the utilization of energy in the production of fruits in Chile in order to improve the efficiency of its use. He found that the energy ratio of fruit production was in the 0.44–2.22 range. As seen in previous research, several studies on the subject of energy utilization, energy input–output analysis and their relationships, mostly concentrated on field crops, have been conducted on agricultural production. The main objective of this research was to investigate the energy use patterns and to analyze energy input–output in the cultivation of some field crops and vegetables, as energy saving and energy efficiency are significant factors in agricultural productions [9].

However, energy is one of the most valuable inputs in agricultural production. The amount of energy used in agricultural production, processing and distribution needs to be adequate in order to feed the rising population and to meet other social and economic goals. Sufficiency of energy and its effective and efficient use are prerequisites for improved agricultural production. It was realized that crop yields and food supplies are directly linked to energy. In developed countries, rise in crop yields were mainly attributed to rise in use of improved commercial energy inputs in addition to improved crop varieties [23].

There has been no previous study conducted on energy and sensitivity analyses of tangerine production in Iran; therefore the aim of this study is to determine the input–output energy balance in tangerine production, specify a relationship between input energies and yield and sensitivity analysis of the energy inputs on tangerine yield in Mazandaran province, one of the most important citrus production centers, in Iran.

2. Materials and methods

This study is conducted in the Mazandaran province. The province is located in the north of Iran, within 36°40' north latitude and 52°50' east longitude. The total area of the Mazandaran province is 143,100 ha, the farming area is 102,000 ha with a share of 71.3%, and the tangerine orchards consist of 23% of total farming area in the province [24]. Data is collected from farmers by using a face-to-face questionnaire performed from June to August 2011.

For estimating the size of required sample Cochran formula [25], is used that eventually statistical sample method is executed by 50 orchards of tangerine:

$$n=\frac{N(t\times S)^2}{(N-1)d^2+(t\times S)^2} \tag{1}$$

where n is the required sample size; N is the number of holdings in target population; t is the reliability coefficient (1.96 which represents the 95% reliability); S^2 is the variance of studied qualification in population; d is the precision (x–X). The permissible error in the sample size is defined to be 5% for 95% confidence. Based on this method of sampling, 50 farms were investigated.

In the orchards of this region, energy sources include human labor, machinery, diesel fuel, farmyard manure, electricity, fertilizers (Nitrogen, Phosphorous, and Potassium), chemicals and irrigation water.

Energy equivalent for machinery is calculated by Eq. (2):

$$ME=E\frac{G}{T} \tag{2}$$

where ME is the machinery energy (MJ h^{-1}), E (=62.7 MJ kg^{-1}) [26] the production energy of machine for tractor, G the weight of machine (kg), and T is the economic life of machine (h).

Based on the energy equivalents of the inputs and outputs (Table 1), the surveyed data including various energy and

Table 1
Energy equivalents of inputs and output in agricultural production.

Particulars	Unit	Energy equivalent (MJ unit^{-1})	Reference
A. Inputs			
1. Human labor	h	1.96	[27]
2. Machinery	h	62.7	[27]
3. Diesel fuel	L	47.8	[28]
4. Chemical fertilizers	kg		
(a) Nitrogen (N)		78.1	[28]
(b) Phosphate (P_2O_5)	17.4		[28]
(c) Potassium (K2O)		13.7	[28]
5. Farmyard manure	kg	0.3	[27]
6. Chemicals	kg	120	[27]
7. Water for irrigation	m^3	1.02	[29]
8. Electricity	kWh	3.6	[28]
B. Output			
1. Tangerine	kg	1.9	[27]

economic indicators can be computed. Specifically, we calculate energy ratio, specific energy, energy productivity, net energy and energy intensiveness are calculated. For economic analysis, net profit, gross return, net return, benefit to cost ratio and productivity are also computed.

Energy demand in agriculture can be divided into direct and indirect energies or renewable and non-renewable energies. Direct energy (DE) covers human labor, diesel and electricity, while indirect energy (IDE) includes energy embodied in fertilizers, chemicals, water for irrigation, farmyard manure, and machinery used in the orchard fruit productions. Renewable energy (RE) consists of human labor, farmyard manure and water for irrigation, whereas non-renewable energy (NRE) includes machinery, diesel fuel, electricity, fertilizers and chemicals.

Production function is a function summarizing the process of conversion of factors into a particular commodity. It is important that the production function describes technology, not economic behavior. Production functions are used to determine the efficient allocation of resources. For this purpose Cobb–Douglass (CD) production function is chosen as the best function in terms of statistical significance and expected signs of parameters. The CD production function is expressed as:

$$Y = f(x)\exp(u) \tag{3}$$

This methodology has been applied to investigate theoretical assumptions for signs of energy input in determining the optimal output levels. The Cobb–Douglass function has been used by several authors to investigate the relationship between various energy inputs and output of agricultural crops [25,30,31]; it is a power function that can be specified in a mathematical form as follows [30]:

$$Y_i = a\prod_{j=1}^{k} X_{ij}^{\alpha_j} e^{e_i} (\mathrm{i}=1,2,\ldots,\mathrm{n};\ \mathrm{j}=1,2,\ldots,\mathrm{k}) \tag{4}$$

Using a linear presentation, the function to be estimated could be written as:

$$ModelI:\ \ln Y_i = a + \sum_{j=1}^{n} \alpha_j \ln(X_{ij}) + e_i i = 1,2,3\ldots50 \tag{5}$$

where Y_i denotes the yield level of the I' th farmer, X_{ij} is the vector inputs used in the production process that stands for energy of human labor (X_1), Machinery (X_2), diesel fuel (X_3), Chemical fertilizers (X_4), Farmyard manure (X_5), Chemicals (X_6), Water for irrigation (X_7) and Electricity (X_8), a is the constant term, α_j represents coefficients of inputs which are estimated from the model and e_i is the error term. In this study, it is assumed that if there is no input energy, the output energy is also zero. Making this assumption excludes the constant term a from Eq. (4), and the equation reduces to:

$$\ln Y_i = a_1 \ln X_1 + a_2 \ln X_2 + a_3 \ln X_3 + \ldots + a_8 \ln X_8 \tag{6}$$

Eq. (5) is expanded in accordance with the assumption that yield is a function of energy inputs and income is a function of expenses input. More specifically, Eq. (5) can be expressed in the following form by using standardized coefficients:

Similarly, the effect of direct, indirect, renewable and non-renewable energies on production yield was investigated using the following equations [5]:

$$\text{Model II}: \ln Y_i = \beta_1 \ln DE + \beta_2 \ln IDE + e_i \tag{7}$$

$$\text{Model III}: \ln Y_i = \gamma_1 \ln RE + \gamma_2 \ln NRE + e_i \tag{8}$$

Eqs. (6) and (7) are expressed by using standardized coefficients. Where Y_i is the ith grower's yield, β_i and γ_i are coefficient of exogenous variables.

In addition to the influence of each variable on the yield level, the impact of expenses and on yield is also investigated. For this purpose, Cobb–Douglas function was specified in the following form Eq. (8);

$$\text{Model IV}: \ln Y_i' = a_1' \ln X_1' + a_2' \ln X_2' + a_3' \ln X_3' + \ldots + a_8' \ln X_8' \tag{9}$$

where Y_i' is the ith farm's income, and α_i' is the coefficient of exogenous variables. Eq. (5) to (8) were estimated using ordinary least square technique.

The Marginal Physical Productivity (MPP) method, based on the response coefficients of the inputs is utilized to analyze the sensitivity of energy inputs on tangerine yield. Sensitivity analysis is especially useful in pinpointing which assumptions are appropriate variables for additional data collection to narrow the degree of uncertainty in the results. Typically, in a sensitivity analysis, as the exogenous parameters are generally varied by a linear proportion, the endogenous variable must linearly depend on those parameters. Also, as the parameters are varied one at a time, different model parameters must not interact in their influence on the endogenous variable [32]. Therefore, the sensitivity analysis of an input imposes the change in the output level with a unit change in the input in model, assuming that all other inputs are constant at their geometric mean level. The MPP of the various inputs was computed using the α_j of the various energy inputs as [30]:

$$MPP_{xj} = \frac{GM(y)}{GM(x_j)} \times \alpha_j \tag{10}$$

where $\mathrm{MPP_{xj}}$ is the MPP of jth input; β_i, regression coefficient of jth input; GM(Y), geometric mean of yield; and GM(X_j), geometric mean of jth input on per hectare basis.

In production, returns to scale refer to changes in output subsequent to a proportional change in all inputs (where all inputs increase by a constant factor). In the Cobb–Douglas production function, it is indicated by the sum of the elasticities derived in the form of regression coefficients. If the sum of the estimated coefficients is greater than unity ($\sum_{i=1}^{n}\alpha_i > 1$), then it could be concluded that the increasing returns to scale, on the other hand if the latter parameter is less than unity ($\sum_{i=1}^{n}\alpha_i < 1$), then it is indicated that the decreasing returns to scale; and, if the result is unity ($\sum_{i=1}^{n}\alpha_i = 1$), it shows that the constant returns to scale [30]. Basic information on energy inputs and tangerine yields are entered into Excel spreadsheets, SPSS 20 spreadsheets. Expressions, such as the energy ratio, the energy productivity, the specific energy, the net energy gain and the energy intensiveness are given by [33], also other expressions stated as energy intensity cost, energy intensiveness value and energy ratio cost that they are given by [34]:

$$\text{Energy ratio} = \frac{\text{Output Energy}(\text{MJ ha}^{-1})}{\text{Input Energy}(\text{MJ ha}^{-1})} \tag{11}$$

$$\text{Energy Productivity} = \frac{\text{Yield}(\text{kg ha}^{-1})}{\text{Input Energy}(\text{MJ ha}^{-1})} \tag{12}$$

$$\text{Net Energy} = \text{Output Energy}(\text{MJ ha}^{-1}) - \text{Input Energy}(\text{MJ ha}^{-1}) \tag{13}$$

$$\text{Energy intensiveness} = \frac{\text{Input Energy}(\text{MJ ha}^{-1})}{\text{Total production cost}(\$\ \text{ha}^{-1})} \tag{14}$$

Net profit, gross return, net return, benefit to cost (BC) ratio and productivity were calculated by [33]:

$$\text{Gross production value} = \text{Yeild}(\text{kg ha}^{-1}) \times \text{Price of Commodity}(\$\ \text{kg}^{-1}) \tag{15}$$

$$\text{Gross return} = \text{Gross production value}(\$\ \text{ha}^{-1}) - \text{Variable production cost}(\$\ \text{ha}^{-1}) \tag{16}$$

$$\text{Net return} = \text{Gross production value}(\$\ \text{ha}^{-1}) - \text{Total production cost}(\$\ \text{ha}^{-1}) \quad (17)$$

$$\text{BC} = \frac{\text{Gross Production value}(\$\ \text{ha}^{-1})}{\text{Total production cost}(\$\ \text{ha}^{-1})} \quad (18)$$

$$\text{Productivity} = \frac{\text{Yeild}(\text{kg ha}^{-1})}{\text{Total production cost}(\$\ \text{ha}^{-1})} \quad (19)$$

Energy intensity cost, Energy intensiveness value and Energy ratio cost were calculated by [34]:

$$\text{Energy intensity cost} = \frac{\text{Total energy cost}(\$\ \text{ha}^{-1})}{\text{Yeild}(\text{kg ha}^{-1})} \quad (20)$$

$$\text{Energy intensiveness value} = \frac{\text{Input energy}(\text{MJ ha}^{-1})}{\text{Gross production value}(\$\ \text{ha}^{-1})} \quad (21)$$

$$\text{Energy ratio cost} = \frac{\text{Total energy cost}(\$\ \text{ha}^{-1})}{\text{Total production cost}(\$\ \text{ha}^{-1})} \quad (22)$$

3. Results and discussion

In this study, the proposed data used is collected from 50 tangerine producers in Mazandaran province. The collected data belong to the production period of 2011(fall season). Average farm size is 1 ha with a range from 0.1 up to 2 ha, and 100% of total land in each farm is irrigated and all of selected farms are privately owned.

3.1. Analysis of input–output energy use in tangerine production

Table 2 shows the inputs consumption and output in tangerine production in the study area. The total energy requirement for producing the tangerine crops is about 62,260 MJ ha^{-1}. Among the different energy sources chemical fertilizers have the highest energy consumption and the maximum use of the chemical fertilizers is 719.5 kg ha^{-1}. Chemicals have the next highest energy consumption of 110.6 kg ha^{-1}. From the total energy of chemical fertilizers, the shares of nitrogen, phosphorus and potassium are around 82.4%, 8.8%, 8.8%, respectively. The inputs energy consumption is least for machinery (1473.5 MJ ha^{-1}) which accounts for about 2.4% of the total energy consumption. The average yield of tangerine is found to be 26,862.5 kg ha^{-1}, accordingly, the total energy output is calculated as 54,059.5 MJ ha^{-1} (Table 2).

Table 2
Energy use pattern for tangerine production.

Quantity (inputs and outputs)	unit	Quantity per unit area (ha)	Total energy equivalent (MJ ha^{-1})	Percentage from total (%)
A. Inputs				
1. Human labor	(h)	1606.8	3149.4	5.1
2. Machinery	(h)	147.1	1473.5	2.4
3. Diesel fuel	(L)	7.3	1595.2	2.6
4. Chemical fertilizers	(kg)	719.5	32630.3	52.4
(a) Nitrogen (N)		344.2	26879.3	43.2
(b) Phosphate (P_2O_5)	164.6	2864.5	4.6	
(c) Potassium (K_2O)		210.7	2886.5	4.6
5. Farmyard manure	(kg)	19172.8	5751.8	9.2
6. Chemicals	(kg)	110.6	13273.2	21.3
7. Water for irrigation	(m^3)	806.5	2016.2	3.2
8. Electricity	(kWh)	658.7	2371.3	3.8
Total energy input	(MJ)		62260.9	100.0
B. Output				
1. Tangerine	(kg)	26862.5	54059.5	

Energy indices including energy ratio, energy productivity, specific energy, net energy, energy intensiveness, energy intensity cost, energy intensiveness cost and energy ratio cost of tangerine production are presented in Table 3.

Energy ratio is calculated as 0.21, showing the 0.21 unit output energy is obtained per unit energy consumption. Similar results for energy ratio have been reported for different crops such as 0.15 for strawberry [2], 0.69 for cucumber [5], 0.74 for cotton [36], 0.66 for garlic [37], 0.47 for tomato [38], 0.61 for eggplant and 0.99 for pepper [39]. The average energy productivity of tangerine is 0.43 kg MJ^{-1}. This means that 0.43 units output is obtained per unit energy consumption. Calculation of energy productivity rate is well documented in the literature such as; garlic (0.42) [37] and cucumber (0.55) [5]. The specific energy, net energy and energy intensiveness of tangerine production are 2.32 MJ kg^{-1}, −8201.4 MJ ha^{-1} and 12.04 MJ \$$^{-1}$, respectively. Net energy is negative (less than zero). Therefore, it can be concluded that in tangerine production, energy is being lost. Similar results obtain 1.24 MJ kg^{-1} for the specific energy of cucumber production [40]. Total energy cost is calculated by converting energy input to barrel of oil and converts it to dollar in indices of energy intensity cost and energy ratio cost. Energy intensity cost, energy intensiveness value and energy ratio cost of tangerine of production are 0.04 \$ kg^{-1}, 7.41 MJ \$$^{-1}$, 0.21, respectively.

Total energy input as direct, indirect, renewable and nonrenewable forms is given in Table 4. The total energy input consumed

Table 3
Energy indices in tangerine production.

Items	Unit	Quantity
Energy input	MJ ha^{-1}	62260.9
Energy output	MJ ha^{-1}	54059.5
Yield	kg ha^{-1}	26862.5
Energy use efficiency	–	0.87
Specific energy	MJ kg^{-1}	2.32
Energy productivity	kg MJ^{-1}	0.43
Net energy	MJ ha^{-1}	−8201.4
Energy intensiveness	MJ \$$^{-1*}$	7.36
Energy intensity cost	\$ kg^{-1}	0.04
Energy intensiveness value	MJ \$$^{-1}$	5.28
Energy ratio cost	–	0.13

* Convert Rial to Dollar [35].

Table 4
Total energy input in the form of direct, indirect, renewable and non-renewable for tangerine production (MJ ha^{-1}).

Form of energy (MJ ha^{-1})	Quantity	Percentage from total (%)
Direct energy[a]	9132.03	14.67
Indirect energy[b]	53128.87	85.33
Renewable energy[c]	10917.38	17.53
Non-renewable energy[d]	51343.52	82.47

[a] Includes electricity, human labor, diesel fuel.
[b] Includes chemical fertilizer, farmyard manure, chemicals, machinery, water for irrigation.
[c] Includes human labor, farmyard manure, water for irrigation.
[d] Includes diesel fuel, electricity, chemicals, chemical fertilizer, machinery.

could be classified as direct energy (14.7%), indirect energy (85.3%) or renewable energy (17.5%) and non-renewable energy (82.5%). Several researchers show that the share of indirect energy (82.35%) is higher than that of direct energy (17.65%), and the ratio of nonrenewable energy (74.27%) is greater than that of renewable energy (25.73%) for potato production in Iran [41], and also, the ratio of indirect energy is higher than that of direct energy and the rate of non-renewable energy is greater than that of renewable energy consumption for cotton production in Turkey [36].

With respect to the obtained results, shown in Fig. 1, the shares of energy consumption in tangerine production consist of 52.4% chemical fertilizer, 21.3% chemicals, 9.2% farmyard manure, 5.1% human labor, 3.8% electricity, 3.2% water for irrigation, 2.6% diesel fuel and 2.4% machinery. The highest portion of energy input incurred by chemical fertilizer, that this is in agreement with results found by Mousavi–Avval et al. [42] for canola production and Mohammadi et al. [41] for potato production. The results reveal that consumption of chemical fertilizers, chemicals, farmyard manure are the highest energy inputs for tangerine production in the region.

3.2. Econometric model estimation of tangerine production

Relationship between the energy inputs and yield was estimated using Cobb–Douglas production function for the tangerine crop on different categories of farms. Tangerine yield is assumed to be a function of human labor, machinery, diesel fuel, chemical fertilizers, farmyard manure, chemicals, water for irrigation and electricity energy. The coefficient of determination (R^2) is 0.83 for this model. The impact of energy inputs on yield is also investigated by estimating Eq. (5). Regression results for this model are shown in Table 5.

It can be seen from Table 5 that the contribution of chemical fertilizer, water for irrigation and electricity energies are significant at the 1% level. This indicates that an additional use of 1% for each of these inputs would lead to 0.84% and 0.36% increase, 0.56% decrease in yield, respectively. Because of using Cobb–Douglas function in the estimation, the coefficient of variables in log form can be regarded as elasticity [25]. The elasticity of machinery is significant at the 5% level. The impact of human labor, diesel fuel, farmyard manure and chemicals energies on yield are estimated statistically insignificant. Rafiee et al. [43] reported that impact of chemical fertilizer, water for irrigation and electricity energy was found to be statistically significant at the 1% level on the stake cucumber yield. Mohammadi et al. [41] estimated an econometric model for potato production in Ardabil province of Iran. They concluded that among the energy

Table 5
Econometric model estimation results of energy inputs.

Endogenous variable: yield	Coefficient	*t*-ratio	MPP
Exogenous variables			
1. Human labor	110	1.114	2.06
2. Machinery	−166	−1.942*	−23.21
3. Diesel fuel	022	280	0.42
4. Chemical fertilizers	838	9.95**	0.96
5. Farmyard manure	027	0.311	0.30
6. Chemicals	−001	−016	−0.005
7. Water for irrigation	356	2.949**	11.48
8. Electricity	−557	−5.074**	−17.70
R^2	0.83		
RTS	0.629		

* and
** indicate significance at 5% and 1% levels, respectively.

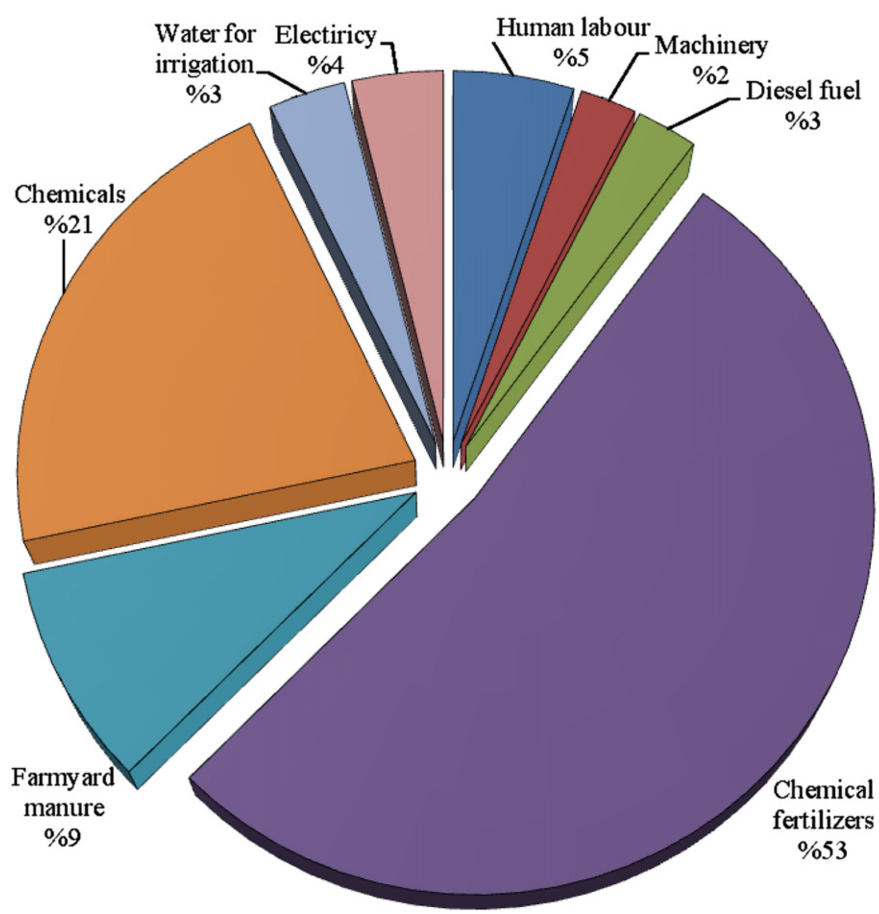

Fig. 1. Distribution of energy consumption from different inputs.

Table 6
Econometric estimation of direct and indirect and renewable and nonrenewable energies.

Exogenous variables	Coefficient	t-Ratio	MPP
DE (b1)	−311	−3.42**	−2.34
IDE (b2)	944	10.36**	0.77
R2	0.804		
RTS	0.632		
RE (g1)	−168	−2.25**	−0.92
NRE (g2)	−870	11.66**	0.73
R2	0.832		
RTS	0.701		

** indicates significance at 1% level.

inputs, chemical fertilizer energy was found as the most important input that influenced the yield.

The results of econometric model development between energy forms and the yield value are presented in Table 6. It is evident that, the regression coefficients of indirect energy and non-renewable energy forms are positive and significant ($p < 1\%$). The regression coefficients of direct energy and renewable energy are also significant ($p < 1\%$). The impacts of DE, IDE, RE and NRE are estimated in the range of −0.31 to 0.94.

3.3. *Sensitivity of energy inputs, DE, IDE, RE and NRE*

3.3.1. *MPP results*

The sensitivity of energy inputs on production is analyzed by using MPP technique based on response coefficient of inputs and results are shown in Table 5. Machinery energy has the major MPP value of 9.56. This indicates that additional utilization of 1 MJ for each of the machinery energy would result in an increase in yield by 9.56 kg. These inputs (exogenous parameters) have a strong impact on the yield (endogenous variable) with large sensitivity coefficients. Rafiee et al. [43] analyzed the sensitivity of energy inputs on apple productivity. They reported that the major MPP was due to water for irrigation energy (2.43).

The values of MPP for DE, IDE, RE and NRE are in the range of 0.12–0.27 (Table 6). This indicates that an additional use of 1 MJ of each of these energy forms would lead to an additional increase in yield by 0.12–0.27 kg.

3.3.2. *Returns to scale results*

The Return to Scale (RTS) values for the econometric models are calculated by gathering the regression coefficients shown in Tables 5, 6 and 8. RTS values of Model I, II, III, IV, for tangerine yield are 0.49, 0.21, 0.19 and 1211.9, respectively; which are a DRS of tangerine for estimated models. The higher values of RTS than unity indicates IRS, whereas the lower value than unity reveals a DRS. This reveals that a 1% increase in the total energy inputs utilized would lead in 0.49% increase in the tangerine yield for model I. In the study of Heidari and Omid [5] for tomato production the sum of the regression coefficients (i.e. values for RTS in Table 5) of energy inputs is calculated less than unity.

3.4. *Economic analysis of tangerine production*

The total cost of tangerine production and the gross value of its production is calculated and shown in Table 7. The fixed and variable expenditure included in the cost of production is calculated separately. According to the results of the research, the total expenditure for the tangerine production is 5173.3 $ ha^{-1} while the gross production value are found to be 8396.9 $ ha^{-1} and the share of variable costs in total costs is 64.2%. With respect to

Table 7
Economic analysis of tangerine production.

Cost and return components	Unit	Value
Yield	kg ha^{-1}	26862.5
Sale price	$ kg^{-1}	0.31
Gross production value	$ ha^{-1}	8396.93
Variable production cost	$ ha^{-1}	3323.73
Fixed production cost	$ ha^{-1}	1849.53
Total production cost	$ ha^{-1}	5173.27
Total production cost	$ kg^{-1}	0.19
Gross return	$ ha^{-1}	5073.20
Net return	$ ha^{-1}	3223.66
Benefit to cost ratio		1.62
Productivity	kg $$^{-1}$	5.19

Table 8
Econometric estimation results of cost inputs.

Endogenous variable: yield	Coefficient	*t*-ratio	MPP
Exogenous variables			
1. Labor expense	−1.791	−50	−0.02
2. Machinery expense	3.178	89	0.54
3. Diesel fuel expense	2.943	38	10.90
4. Chemical fertilizers expense	4.019	1.40	0.05
5. Farmyard manure expense	1.346	0.32	0.12
6. Electricity expense	−2.128	−35	−0.21
7. Poison expense	0.436	29	0.02
8. Packaging expense	−1.110	−66	−0.03
9. Rant land expense	−0.001	−0.24	−0.01
R^2	876		
RTS	6.89		

* and ** indicate significance at 5% and 1% levels, respectively.

results of Table 7 and the benefit cost ratios from tangerine productions in orchard is calculated to be 1.62. Other researchers on agricultural productions reported similar results, such as: 1.68 for greenhouse cucumber, 3.28 for greenhouse tomato [5], 0.86 for cotton [30], 1.74 for strawberry [3], 2.09 for canola [41], 2.37 for orange, 1.89 for lemon and 1.88 for mandarin [39].

The results of econometric model development between costs of inputs and the yield value are presented in Table 8. Regression results for this equation show among the variables included in the model, chemical fertilizers and machine expenses are found as the most important variables that influence income. The elasticity for chemical fertilizers and machine expenses are 4.019 and 3.178, implying that a given 1% change in chemical fertilizers and machine expenses will result in 4.019% and 3.178% increase in income, respectively. The third important input is found as diesel fuel with 2.943 elasticity. Other important variables that influence tangerine income are electricity and human labor with elasticity of −2.128 and −1.791, respectively.

4. Conclusions

Based on the present paper following conclusions are drawn:

1. The total energy consumption in tangerine production is about 62 GJ ha^{-1}. Chemical fertilizer and chemicals are found the most energy consuming inputs among all energy sources. Organic methods such as Integrated Nutrient Management, which contains manure, organic fertilizer, biological fertilizer and chemical fertilizer, can be used to reduce energy of chemical fertilizers. Farmers can use biological and physical methods to decrease energy of chemicals. Farmyard manure

has the tertiary share within the total energy inputs. Energy output is calculated as 54 GJ ha^{-1}. Accordingly, Indirect (about 53 GJ ha^{-1}) and non-renewable (about 51 GJ ha^{-1}) energies are rather high.

2. Tangerine production in the region showed a high sensitivity on nonrenewable energies which may result in both the environmental deterioration and rapid rate of depletion of these energetic resources. Therefore, policies should emphasize development of new technologies to substitute fossil fuels with renewable energy sources aiming efficient use of energy and lowering the environmental footprints.
3. Energy ratio, energy productivity, specific energy, net energy and energy intensiveness of tangerine production are 0.87, 0.43 kg MJ^{-1}, 2.32 MJ kg^{-1}, -8201.4 MJ ha^{-1}, and 7.36 MJ $\$^{-1}$, respectively.
4. The benefit–cost ratio is found to be 1.62 according the result of economical analysis of tangerine production. The mean net return and productivity from tangerine production is obtained as 3223.7 \$ ha^{-1} and 5.2 kg $\$^{-1}$, respectively.
5. From the econometric estimation results of cost inputs, the elasticity estimate of chemical fertilizers cost is found as 4.02 with positive sign, which has the major impact on tangerine production, followed by machinery (3.18), diesel fuel (2.94) and electricity (−2.13).
6. Applying a better machinery management technique, utilization of alternative sources of energy such as organic fertilizers, improving timing, amount and reliability of water application and utilization of new irrigation systems may be suggested to establish the sustainable and cleaner food production systems.

References

[1] Lohrasbi M, Pourbafrani M, Niklasson C, Taherzadeh MJ. Process design and economic analysis of a citrus waste biorefinery with biofuels and limonene as products. Bioresource Technology 2010;101:7382–8.
[2] Banaeian N, Omid M, Ahmadi H. Energy and economic analysis of greenhouse strawberry production in Tehran province of Iran. Energy Conversion and Management 2011;52:1020–5.
[3] Ram RA, Raghuvanshi NK, Arya, SV. Study on energy cost requirements for wheat cultivation, Paper No: 80–105. Presented at ISAE. XVII Annual Convention, New Delhi; February 6–8, 1980.
[4] Gezer I, Acaroglu M, Haciseferogullari H. Use of energy and labour in apricot agriculture in Turkey. Biomass and Bioenergy 2003;24(3):215–9.
[5] Heidari MD, Omid M. Energy use patterns and econometric models of major greenhouse vegetable productions in Iran. Energy 2011;36:220–5.
[6] Singh H, Mishra D, Nahar NM. Energy use pattern in production agriculture of a typical village in arid zone. India–part I. Energy Conversion and Management 2002;43:2275–86.
[7] Rathke GW, Diepenbrock W. Energy balance of winter oilseed rape (Brassica napus L.) cropping as related to nitrogen supply and preceding crop. European Journal of Agronomy 2006;24:35–44.
[8] Elez Martinez P, Escola Herna ndez J, Soliva Fortuny RC, Martin Belloso O. Inactivation of Lactobacillus brevis in tangerine juice by high-intensity pulsed electric fields. Food Microbiology 2005;22:311–9.
[9] Canakci M, Topakci M, Akinci I, Ozmerzi A. Energy use pattern of some field crops and vegetable production: case study for Antalya Region, Turkey. Energy Conversion and Management 2005;46:655–66.
[10] WEC World Energy Council. Renewable energy in South Asia, 〈www.worldenergy.org/ documents/saarc.pdf〉; 2000.
[11] IEA. World energy outlook 2001. International Energy Agency; 2001.
[12] Pimentel D. Handbook of energy utilization in agriculture. Boca Raton, FL: CRC Press; 1980.
[13] Singh H, Mishra D, Nahar NM. Energy use pattern in production agriculture of a typical village in arid zone India-part I. Energy Conversion Management 2002;43:2275–86.
[14] Wall G. Exergy-a useful concept within resource accounting. Report no.77–42 Institute of Theoretical Physics, Goteborg, Sweden; 1977.
[15] Wall G. Exergy-a useful concept. Thesis. Chalmers Uni Tech, Goteborg, Sweden; 1986.
[16] Chen GQ. Exergy consumption of the Earth. Ecological Modeling 2005;184: 363–380.
[17] Chen GQ. Scarcity of exergy and ecological evaluation based on embodied exergy. Communications in Nonlinear Science and Numerical Simulation 2006;11:531–52.
[18] Szargut J. International process in second law analysis. Energy 1980;5: 709–718.
[19] Szargut J. Exergy Method and Its Application in Ecology. Newcastle, UK: WIT Press; 2004.
[20] Szargut J, Dziedziniewicz C. Energie utilizable des substances chimiques inorganiques. Entropie 1971;40:14–23.
[21] Szargut J, Morris DR. Calculation of the standard chemical exergy of some elements and their compounds, based upon sea water as the datum level substance. Bulletin of the Polish Academy of Sciences Technical Sciences 1985;33(5-6):292–305.
[22] Thankappan S, Midmore P, Jenkins T. Conserving energy in smallholder agriculture: a multi-objective programming case-study of northwest India. Ecological Economics 2006;56:190–208.
[23] Ozkan B, Ceylan RF, Kizilay H. Comparison of energy inputs in glasshouse double crop (fall and summer crops) tomato production. Renewable Energy 2011;36:1639–44.
[24] Anonymous. Annual agricultural statistics. Ministry of Jihad-e-Agriculture of Iran, 〈www.maj.ir〉; 2011.
[25] Ghasemi Mobtaker H, Keyhani A, Mohammadi A, Rafiee S, Akram A. Sensitivity analysis of energy inputs for barley production in Hamedan province of Iran. Agriculture, ecosystems and environment 2010;137:367–72.
[26] Singh S, Pannu CJS, Singh S, Singh IP, Kaur S. Energy in Punjab agriculture. PAU Ludhiana: Department of Farm Power and Machinery; 1996.
[27] Singh S, Mittal JP. Energy in production agriculture. New Delhi: Mittol Pub; 1992.
[28] Kitani OCIGR. Handbook of Agricultural Engineering. vol. 5. Energy and Biomass Engineering. St Joseph, MI: ASAE publication; 1998.
[29] Acaroglu M. Energy from biomass and applications. University of Selcuk Graduate School of Natural and Applied Sciences. Textbook; 1998.
[30] Singh G, Singh S, Singh J. Optimization of energy inputs for wheat crop in Punjab. Energy Conversion and Management 2004;45:453–65.
[31] Hatirli SA, Ozkan B, Fert C. Energy inputs and crop yield relationship in greenhouse tomato production. Renewable Energy 2006;31:427–38.
[32] Drechsler M. Sensitivity analysis of complex models. Biological Conservation 1998;86:401–12.
[33] Omid M, Ghojabeige F, Ahmadi H, Delshad M. Energy use pattern and benchmarking of selected greenhouses in Iran using data envelopment analysis. Energy Conversion and Management 2011;52(2):153–62.
[34] Rezapoor R, Zarbakhsh MH. Fundamentals of Energy Conservation & Energy Management Principles.3rd ed. Iran: Ministry of power; 2009.
[35] Central Bank of Iran (CBI), 〈www.cbi.ir〉; [19.12.11].
[36] Yilmaz I, Akcaoz H, Ozkan B. An analysis of energy use and input costs for cotton production in Turkey. Renewable Energy 2005;30:145–55.
[37] Samavatean N, Rafiee S, Mobli H, Mohammadi A. An analysis of energy use and relation between energy inputs and yield, costs and income of garlic production in Iran. Renewable Energy 2010;36:1808–13.
[38] Behesti I, Keyhani A, Rafiee S. Energy balance in Iran's agronomy (1990–2006). Renewable and Sustainable Energy Reviews 2010;14:849–55.
[39] Ozkan B, Kurklu A, Akcaoz H. An input–output energy analysis in greenhouse vegetable production: a case study for Antalya region of Turkey. Biomass and Bioenergy 2004;26:189–95.
[40] Mohammadi A, Omid M. Economical analysis and relation between energy inputs and yield of greenhouse cucumber production in Iran. Applied Energy 2010;87:1–6.
[41] Mohammadi A, Tabatabaeefar A, Shahin S, Rafiee S, Keyhani A. Energy use and economical analysis of potato production in Iran a case study: Ardabil province. Energy Conversation and Management 2008;49:3566–70.
[42] Mousavi-Avval SH, Rafiee S, Jafari A, Mohammadi A. Improving energy use efficiency of canola production using data envelopment analysis (DEA) approach. Energy 2011;36:2765–72.
[43] Rafiee S, Mousavi Avval SH, Mohammadi A. Modeling and sensitivity analysis of energy inputs for apple production in Iran. Energy 2010;35:3301–6.